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Radiation Considerations in the Design of the Neutral Dump close to LHC Interaction Regions

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1. Introduction

About 23% of the energy in 7+7 TeV p-p interactions (1.642 TeV) is carried by neutral particles which will pass through the aperture of the low-beta quadrupoles on either side of an LHC interaction region. The number and energy spectrum of these particles has been calculated using the DTUJET93 code [Aur94], which is based on the dual topological unitarization model for hadronic multiple particle production. Figure 1 shows the energy spectra of photons and neutral hadrons downstream of the first dipole D1 integrated out to an angle of 0.583 mrad, corresponding to a radius of 35 mm at a distance of 60 m. The data of Figure 1 are based on 30000 inelastic p-p collisions, including single and double diffractive events. The average energy of these neutral particles is high, being 0.63 TeV for the photons and 2.26 TeV for the neutral hadrons, mainly neutrons. Throughout this paper we assume the LHC luminosity of 10^{34} cm^{-2}s^{-1}, and the total inelastic cross-section of 80 mb as calculated with DTUJET93. This corresponds to a p-p interaction rate of 8×10^8 s^{-1} and means that approximately 210 watts of power will have to be absorbed by the neutral dump on either side of each interaction region.

2. The Calculation

For this preliminary study, the neutral dump was assumed to be a cylinder of copper of density 8.92 g/cm^3, 3 m long and 5 cm radius, surrounded by an iron cylindrical shield (density 7.86 g/cm^3) over its whole length of 85 cm outer radius.

The hadron and electromagnetic cascades in the dump were simulated with the MARS12 Monte-Carlo code [Mok89, Mok93].

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3. Dose

Contours of the power density in the dump are illustrated in Figure 2 and the distribution of absorbed power density along the beam axis is given in Figure 3. The maximum value is 80 W/kg. Even though the total power absorbed by the dump and the peak power density are not large, water-cooling of the dump would appear to be prudent.

The total power leaving the back face of the dump is 16 mW; this should be of no consequence to any cryogenic equipment placed behind the dump. Figure 4 shows how this escaping power varies with the length of the dump.

Figure 5 gives the longitudinal variation of power density at the copper/iron interface and at the outer face of the iron. Figure 6 is a similar plot of the radial variation of power density at depths of 30 cm, 100 cm and 300 cm. For 10^7 operating seconds in a year, the annual dose received by an object directly alongside the dump could reach 40 Gy; doses at the walls of the tunnel will be between 3 to 10 times lower than this value. These doses should not be high enough to destroy any radiation-sensitive equipment installed in this area. Immediately behind the dump, the annual dose will be between one and two orders of magnitude lower than the dose alongside the dump except on the beam axis. The low values of these doses could lead to a re-consideration of the optimum size of the dump.

4. Dose rates from induced radioactivity

In MARS12 the hadron energy threshold for star formation is 47 MeV for protons and neutrons and 191 MeV for charged pions. These thresholds are the same as the FLUKA threshold for star production so that it is possible to use the same conversion factor for estimating the remanent dose rate from the star density, *viz.* a star production rate of 1 $cm^{-3}.s^{-1}$ in iron or copper will give rise to a dose rate of 10^{-8} Sv/h after a 30 day irradiation with 1 day of cooling down time [Tho88]. Contours of the star density production rate are illustrated in Figure 7 and remanent dose rates on the outer surface of iron cylindrical shields of 25, 55 and 85 cm radius are given in Figure 8. For the 85 cm radius shield the remanent dose rate on the outer face of the dump will not exceed 10 μSv/h. Remanent dose rates close to the front face of the dump and over the back face for sumps of 2 and 3 m long are given in Figure 9. It can be seen that the maximum dose rate on the axis of the 3 m dump will be several hundred μSv/h.

5. Conclusions

The dimensions of the neutral beam dump chosen for the present study would appear to give a very high degree of protection against both prompt and remanent dose rates. We would therefore propose that the neutral dumps for LHC interaction regions should have outer dimensions of approximately 130 cm diameter and 250 cm long. The diameter of the inner copper cylinder should be determined from heat transfer calculations. However other considerations such as the magnitude of any ground-water activation may also have to be taken into account. When further discussions have taken place on the size and position of the neutral beam dumps, then more detailed calculations can be made to estimate prompt and remanent dose rates.

References

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